BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Review of Proposed Communication System for the Experiment Carrier Module for AAP Mission 1A - Case 620

DATE: December 29, 1967

FROM: A. G. Weygand

ABSTRACT

The communications system design for the Experiment Carrier Module as proposed by the Martin Marietta Corporation during the Preliminary Requirements Review conducted on December 13-15, 1967 is described. The operational limitations and other shortcomings of this proposed design are discussed. These include: (a) inflexibility of telemetry subsystem design to accommodate changes in data transfer requirements. (b) incompatibility of telemetry subsystem design with real-time data requirements, (c) limitation of ground control of subsystems and experiments, (d) problem areas in implementation of tape recorder-reproducer subsystem design, (e) antenna subsystem radiation patterns, and (f) no provision in system design for equipment redundancy or alternate modes of subsystem operation for contingencies.

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MEMORANDUM FOR FILE

1.0 INTRODUCTION

The Preliminary Requirements Review (PRR) for the Experiment Carrier Module (ECM) was conducted at the Martin Marietta Corporation (MMC) location in Denver, Colorado on December 13, 14, and 15, 1967. The ECM is planned for use in conjunction with the Command and Service Module (CSM) in mission AAP-1A of the Apollo Application Program (AAP). A PRR is an informal technical review of the basic approach to the design of the various systems of a contract end item and is held prior to the Preliminary Design Review (PDR). After a general session when the program status and projected schedules were discussed, the approved mission experiments and mission operations were briefly summarized, and the technical approach to the design of the various ECM systems were presented by MMC, a number of working groups were formed to conduct an in-depth review of the basic approach to the design of specific ECM systems proposed by MMC. One of these working groups was concerned with the review of the proposed ECM communications systems design. Mr. A. G. Weygand of Bellcomm, Inc. was a participant in the activities of this working group.

No data package was made available to the members of this working group. The block diagram of the proposed ECM communications system presented during the general session of this PRR did not adequately describe either the proposed system design or its operational modes, and no other documentation existed describing the MMC proposal for the ECM communications system baseline design. Through questions directed to the MMC representatives of this working group, the proposed ECM communications system baseline design was ascertained. A number of recommendations were made for changes in the ECM communications system design but few were adopted. It was agreed by the members of the group that it would be highly desirable for reasons of mission control and experiment data processing to (a) include all ECM subsystem status and/or performance data and experiment data (excluding video data) to be transmitted in real time in a single PCM signal consisting of 8 bit words, (b) include all ECM subsystem status and/or performance data and experiment data (excluding video data) to be recorded and later dumped in a different single PCM signal consisting of 8 bit words, and (c) to provide the capability for ground-based control of ECM systems and experiments as may be required during periods of crew sleep or peak activity. However, it was recognized that these objectives were not compatible with the type of output data from experiments and the ground rule that existing flight qualified hardware be used wherever possible which had been applied to the design of the ECM communications system for cost and schedule reasons.

The purpose of this memorandum is to present a description of the current MMC baseline design of the communications system of the ECM (Section 3.0) and to discuss the operational limitations and other shortcomings of this design (Section 4.0). A brief description of mission AAP-1A as currently envisioned is included in Section 2.0 for the reader's information.

2.0 MISSION DESCRIPTION

The flight hardware required for the Apollo Applications Program (AAP) mission AAP-1A includes an Uprated Saturn I Launch Vehicle, a Spacecraft Lunar Module Adapter (SLA), an Experiment Carrier Module (ECM), a Block II Command and Service Module (CSM), and a Launch Escape System (LES).

Mission 1A will be manned and will be launched from Cape Kennedy into an elliptical Earth orbit of approximately 87 by 140 nautical miles altitude with an inclination of approximately 50 degrees. After insertion into Earth orbit, the CSM will separate from the SLA and will transpose and hard dock to the ECM. The CSM/ECM will separate from the S-IVB/IU/SLA and will be placed in a circular Earth orbit of approximately 140 nautical miles altitude by the propulsion system of the SM. The mission will be open-ended with a planned mission duration of 14 days during which time Earth resource and meteorological experiments will be conducted. The specific experiments which have been approved by the Manned Space Flight Experiments Board (MSFEB) for mission AAP-1A are listed in Table 1. Group 1 experiments are those experiments which will be conducted only during CSM/ECM overflight of the continental United States and immediate surrounding areas while Group 2 experiments may be conducted at anytime. During the conduct of these experiments but not necessarily throughout the mission (such as during crew sleep periods), the CSM/ECM will nominally be stabilized with the roll axis of the CSM/ECM coincident with the local vertical, with the dome of the ECM pointed toward the Earth, and with the docking windows of the CM oriented forward along the space vehicle velocity vector. At the completion of the mission, the CM will return to Earth with the crew via a water landing.

3.0 COMMUNICATIONS SYSTEM OF THE EXPERIMENT CARRIER MODULE

3.1 General

The ECM will be equipped with independent instrumentation and telemetry systems for the processing and transfer of the required ECM subsystem status and/or performance data as well as experiment data to the Manned Space Flight Network (MSFN) and for the processing and on-board display of appropriate subsystem and experiment data for crew assessment. A portable display and control panel will be stored in the ECM during launch and will be relocated to the CSM during the mission to permit crew monitoring and control of ECM subsystems and experiments from the CM. This panel will utilize part of the capability of the electrical interface connectors between the CSM and the ECM. The instrumentation and telemetry systems of the ECM will be described in greater detail in the following paragraphs. A block diagram of the instrumentation and telemetry systems is shown in Figure 1.

In order to meet the requirements for missions AAP-1 and AAP-3, the CSMs used for these missions will be provided with three 61 pin electrical interface connectors. A similar CSM will be used for mission AAP-1A providing the feed through capability for 183 wires. Twenty-four of these pins will be required for the purpose of separating the ECM from the SLA attach points. Approximately 80 pins will be required for the display and control panel.

Timing required for ECM subsystems and experiment data correlation and operation will be provided by the Central Timing Equipment (CTE) of the Block II CSM. The IRIG-B timing format (100 pps) output of the CTE will be routed through the CSM/ECM electrical interface connectors to the ECM measuring subsystem.

Command and control of the ECM subsystems and experiments from the Earth will be accomplished by utilizing the S-band up-data receiving and decoding system of the CM and routing discrete commands through the CSM/ECM electrical interface connectors to the ECM subsystems. The capability to accommodate a total of four discrete commands will be provided in the interface connectors.

Voice communications among the crew and the MSFN will be provided by the audio centers and radio frequency communications systems of the CSM. The umbilical of the personal communications systems (includes duplex voice communications and biomedical data transfer) of the crewmen will be lengthened to permit a crewman to enter the ECM from the CM and perform the required operations while maintaining continuous hardline connection to one of the audio centers of the CM. All voice recording requirements will be fulfilled utilizing existing CM equipments.

3.2 Instrumentation and Telemetry System

The instrumentation and telemetry system of the ECM will include the following subsystems: (a) measuring, (b) PCM telemetry, (c) frequency division multiplexing telemetry, (d) tape recorder-reproducer, (e) VCO mixer, (f) radio frequency equipment, and (g) antennas. The instrumentation and telemetry system design includes the capability for in-flight system calibration.

3.2.1 Measuring Subsystem

The measuring subsystem will consist of sensors, transducers, and signal conditioning equipments. The measuring subsystem, in general, will convert the quantity to be measured into an electrical signal and will condition the resulting electrical signal to be acceptable to either the PCM telemetry subsystem or the frequency division multiplexing telemetry subsystem. For the case of data from various experiments, the sensors and transducers will generally be contained within the respective experiment packages and electrical signals will be available on the output leads of the respective experiment packages. These electrical output signals from various experiments will be conditioned by the measuring subsystem as required to be acceptable to either the PCM telemetry subsystem or the frequency division multiplexing telemetry subsystem. It should be noted that experiments S043, S049, S075, S104, and S105 have digital outputs which cannot be handled by the planned PCM telemetry subsystem and as a result a frequency division multiplexing telemetry subsystem will be included in the ECM for the transfer of this digital data to the MSFN. The output from the experiment S039 which is also incompatible with the planned PCM telemetry subsystem will be a wideband frequency multiplexed composite signal which includes video channel(s), a spacecraft timing signal, and a reference frequency and will be handled independently.

The IRIG-B timing signal transferred to the ECM from the CTE in the CM will be converted in the ECM to a 25 bit IRIG binary coded decimal parallel time word giving the day, the hour, the minute, and the second from a given reference. This word will be conditioned and routed to both the PCM and frequency multiplexing telemetry subsystems for transfer to the MSFN and to the S039 experiment package for transfer to the MSFN to provide a time reference for the data collected onboard the ECM and transmitted to the MSFN in real time or delayed time.

3.2.2 PCM Telemetry Subsystem

The PCM telemetry subsystem will include high level and low level analog multiplexers, a programmer, an analog-to-digital converter, a sync generator, a clock generator, and ancillary equipments, all of which will be of the type used in the Gemini spacecraft. The programmer will be used to combine in digital form the commutated and non-commutated data fed to the PCM telemetry subsystem from the measuring subsystem of the ECM with synchronization words to form two PCM wavetrains, a serial binary coded non-return-to-zero-level (NRZ-L) signal of 51.2 kilobits per second (kbps) and a return-to-zero (RZ) signal of 5.12 kbps. These PCM wavetrains will be composed of words consisting of eight data bits arranged with the most significant bit first. Digital and bi-level data, such as event occurrence data, will be grouped into sets of eight consecutive bits. The 5.12 kbps PCM wavetrain will contain every tenth word contained in the 51.2 kbps PCM wavetrain. All input data will appear at some time in the 51.2 kbps PCM wavetrain but will not necessarily appear at any time in the 5.12 kbps PCM wavetrain. The programmer will have a single fixed program which must be used throughout the mission.

Except during conduct of experiment S103, Short Wavelength Spectrometer, all data to be transferred to the MSFN via the PCM telemetry subsystem (including ECM subsystem status and/or performance data, timing data, data from Group 1 experiments, and analog data from Group 2 experiments) will be contained in the 5.12 kbps PCM signal. The output data from experiment S103 will exceed the remaining capacity of the 5.12 kbps PCM format and consequently during its conduct the 51.2 kbps PCM format must be used to permit transfer of ECM subsystem status and/or performance data, timing data, data from Group 1 experiments, and analog data from Group 2 experiments.

The 5.12 kbps PCM wavetrain will always be routed to the VCO mixer subsystem and except during performance of the S103 experiment will be simultaneously fed to the tape recorder-reproducer subsystem. During conduct of experiment S103, the 51.2 kbps PCM wavetrain will be routed to the tape recorder-reproducer subsystem in place of the 5.12 kbps PCM wavetrain. Switch interlocks with experiment S103 will be provided to insure that the 51.2 kbps PCM wavetrain is routed to the tape recorder-reproducer subsystems during performance of that experiment.

3.2.3 Frequency Division Multiplexing Telemetry Subsystem

The frequency division multiplexing subsystem will include five voltage controlled oscillators (VCO) whose center frequencies correspond to the subcarrier frequencies of FM proportional-bandwidth subcarrier channels 5 through 9, inclusive, defined in the Inter-Range Instrumentation Group (IRIG) Telemetry Standards for frequency division multiplexing telemetry systems. One of the VCOs will be frequency modulated by a spacecraft timing signal routed from the ECM measuring subsystem. The remaining four VCOs will be frequency modulated separately by different properly conditioned digital data outputs from the Group 2 experiments. The 3750 bps digital output from the S049 experiment, IR Interferometer Spectrometer, of the Group 2 experiments will be the only experiment digital output data not handled by either the PCM telemetry subsystem or by the frequency division multiplexing telemetry subsystem.

The frequency division multiplexed composite signal of five frequency modulated subcarriers (IRIG channels 5 through 9, inclusive) will be routed simultaneously to the tape recorder-reproducer subsystem and to the VCO mixer subsystem. The 3750 bps digital wavetrain output from the S049 experiment after conditioning will be routed directly to the tape recorder-reproducer subsystem.

3.2.4 Tape Recorder-Reproducer Subsystem

The tape recorder-reproducer subsystems of the ECM will be a slightly modified version of the fourteen track tape recorder-reproducer subsystem produced by the Leach Corporation for use in the Block II CSM of the Apollo Program. This tape recorder-reproducer subsystem will be modified (a) to record PCM data at a rate of 5.12 kbps at a tape speed of 3.75 inches per second (ips) instead of 1.6 kbps and (b) to playback at a rate of 60 ips instead of 120 ips. The 3750 bps digital waveform will be recorded as an analog signal and it is not expected that modification of the tape recorder-reproducer subsystem will be required to accommodate this signal.

The tape recorder-reproducer subsystem will be capable of recording simultaneously at a record tape speed of 3.75 ips (a) 5.12 kbps PCM wavetrains, (b) a 3750 bps digital waveform, and (c) a frequency division multiplexed signal composed of IRIG FM proportional-bandwidth subcarrier channels 5 through 9, inclusive or of recording simultaneously at a record tape speed of 15 ips (a) 51.2 kbps PCM wavetrain, (b) a 3750 bps digital waveform, and (c) a frequency division multiplexed signal composed of IRIG FM proportional-bandwidth subcarrier channels 5 through 9, inclusive. The playback electronics of this subsystem will permit parallel playback of all recorded data at a playback tape speed of only 60 ips regardless of the record tape speed. The capacity of the tape recorder will be one-half hour of recording at a tape speed of 15 ips and two hours of recording at a tape speed of 3.75 ips. The tape recorder must be rewound before recorder contents can be dumped. The tape recorder contents can be dumped in 7.5 minutes maximum.

The output of the playback electronics of this subsystem associated with the tracks used to record the 5.12 kbps PCM wavetrain or the 51.2 kbps PCM wavetrain will be routed directly to one of the three VHF FM transmitters of the ECM and always to the same one of the three. The outputs of the playback electronics of this subsystem associated with the tape track used to record the 3750 bps waveform and associated with the tape tracks used to record the frequency division multiplexed signal composed of IRIG FM proportional-bandwidth subcarrier channels 5 through 9, inclusive will both always be routed to the VCO mixer subsystem.

3.2.5 VCO Mixer Subsystem

The VCO mixer subsystem will include two voltage controlled oscillators (VCO) both with a center frequency corresponding to the subcarrier frequency of IRIG FM proportional-bandwidth subcarrier channel 19 and the circuitry required (a) to frequency division multiplex either of the two channel 19 VCOs with the output of the tape recorder-reproducer subsystem playback electronics associated with the tape track used to record the 3750 bps digital waveform and (b) to frequency division multiplex the remaining channel 19 VCO with the output of the playback electronics associated with the tape track used to record the frequency division multiplexed signal composed of IRIG FM proportional-bandwidth subcarrier channels 5 through 9, inclusive. The real-time 5.12 kbps RZ PCM wave-train routed from the PCM telemetry subsystem will be used to frequency modulate one of the two channel 19 VCOs in the VCO mixer. The real-time frequency division multiplexed composite signal of five frequency modulated subcarriers (IRIG FM proportional-bandwidth channels 5 through 9, inclusive) from the frequency division multiplexing telemetry subsystem will be used to frequency modulate the second of the two channel 19 VCOs in the VCO mixer.

The composite signal containing the recorder playback of the 3750 bps waveform will be routed directly from the VCO mixer to one of the three VHF FM transmitters of the ECM but always to the same one of the three. The composite signal containing the recorder playback of the IRIG FM channels 5 through 9 will be routed directly from the VCO mixer to another of the three VHF FM transmitters of the ECM but always to the same one.

3.2.6 Radio Frequency Transmitters

The ECM will be equipped with three wideband FM transmitters operating in the VHF telemetry frequency band (225-260 MHz) and one wideband FM transmitter operating in the S-band at a frequency of 2282.5 MHz. The output power of each of these four FM transmitters will be 10 watts minimum. The transmitters will be capable of simultaneous operation on a non-interference basis.

The S-band FM transmitter will be used exclusively to transmit to the MSFN the wideband composite signal output from experiment S039, Day/Night Camera.

One of the three VHF FM transmitters will be used exclusively for the transmission to the MSFN of tape recorder-reproducer subsystem dump of the recorded 5.12 kbps or 51.2 kbps PCM wavetrain generated by the PCM telemetry subsystem. Tape recorder-reproducer subsystem playback dump of the recorded 3750 bps digital waveform generated by experiment S049 for transmission to the MSFN will be associated exclusively with the second of the three VHF FM transmitters. Tape recorder-reproducer subsystem playback dump of the recorded composite signal of IRIG FM proportional-bandwidth subcarrier channels 5 through 9 for transmission to the MSFN will be associated exclusively with the third of the three VHF FM transmitters. The real-time 5.12 kbps RZ PCM signal from the PCM telemetry system modulated on a channel 19 VCO will be frequency multiplexed with the recorder dump data as appropriate to be transmitted to the MSFN via either one of the second and third of the three VHF FM transmitters. The real-time composite signal of IRIG proportional-bandwidth subcarrier channels 5 through 9 modulated on a channel 19 VCO will be frequency multiplexed with the recorder dump data as appropriate to be transmitted to the MSFN via the other one of the second and third of the three VHF FM transmitters.

3.2.7 Antenna Subsystems

The two independent antenna subsystems mounted on the ECM will include a multi-element, omni-directional S-band antenna subsystem and a multi-element, omni-directional VHF antenna subsystem.

The S-band antenna subsystem will consist of four elements located on the ECM and spaced approximately 90 degrees apart. The S-band transmitter output will feed the four S-band antenna elements simultaneously through a four-way power splitter.

The VHF antenna subsystem will consist of four elements located on the ECM and spaced approximately 90 degrees apart. The outputs of the three VHF FM transmitters will be multiplexed. The output of the VHF multiplexer will feed the four VHF antenna elements simultaneously through a four-way power splitter.

4.0 DISCUSSION OF PROBLEM AREAS IN PROPOSED BASELINE DESIGN OF ECM COMMUNICATIONS SYSTEM

The baseline design of the communications system of the ECM to be used in conjunction with the CSM for mission AAP-1A proposed by the Martin-Marietta Corporation and described earlier in this memorandum has operational limitations and other shortcomings which will be discussed in the following paragraphs. These include:

(a) Inflexibility of telemetry subsystem design with regard to changes in total data transfer requirements from the ECM to the MSFN.

(b) Incompatibility of telemetry subsystem design with requirements for real-time or near real time data processing by the MSFN for transfer to the Mission Control Center at Houston for mission control.

(c) Limitation to four the number of discrete commands available to the MSFN for independently controlling operation of ECM subsystems and ECM mounted experiments.

(d) Unsuitability of the Block II CM tape recorder-reproducer subsystem for proposed application in the ECM.

(e) Real time correlation of experiment data with space vehicle attitude, with timing, and with voice communications is impractical if not impossible in some cases.

(f) Question of the suitability of radiation patterns of the VHF and S-band antenna subsystem of the ECM and the CSM.

(g) Absence of equipment redundancy or operational flexibility for contingencies in subsystem design in order to enhance reliability and probability of mission success.

4.1 Inflexibility of Telemetry Subsystem Design

The design of the ECM telemetry subsystem was tailored to meet the specific experiment data transfer requirements listed in the document, "Experiment Requirements - New Baseline", MMC reference no. 7W16234, dated December 5, 1967, reference NASA TWX dated November 28, 1967 and as a result has only limited flexibility to adapt to changes in the number and kinds of output data from the approved experiments or additional experiments. It should be noted that many of the experiments approved for mission AAP-1A have not yet been designed in detail. Consequently the data transfer requirements currently available are only estimates made by the respective principal investigators (PI) often based on experience from other programs and knowledge of communications systems used in other programs and as such are subject to change after the experiment design and the hardware are completed. It is important that the PIs be made aware of general characteristics and data transfer capabilities of the telemetry systems which might be available on-board the ECM and the capabilities of the MSFN for data processing. For instance, for a PCM telemetry system these should include: (a) number of bits per word (quantization error), (b) channel sampling rates, (c) digital data handling capabilities, etc. Armed with this information, the PIs should examine in detail the data transfer requirements of their respective experiment and document their specific requirements in detail. Only after these steps have been taken can the telemetry subsystem of the ECM be designed effectively.

A general ground rule for the design of the ECM communications system was to use existing flight qualified hardware wherever possible. As a consequence, the PCM telemetry subsystem developed for the spacecraft in the Gemini Program was selected for use in the ECM. Since this telemetry subsystem quantizes analog samples into 8 bit words, the subsystem cannot accommodate data requiring 10 bit accuracy. Further this subsystem does not have the capability to integrate free running digital data into its output PCM bit stream. These data which could not be accommodated by the PCM telemetry subsystem of the ECM will be put on subcarriers (five) to form a frequency division multiplexed telemetry signal for transmission to the MSFN in addition to the PCM signal. The PCM telemetry subsystem of the ECM has sufficient spare capacity to accommodate with little impact any reasonable increase in experiment data compatible with its capabilities. However, if a requirement arose for the transfer of additional experiment data which was incompatible with the PCM telemetry subsystems, at least one additional subcarrier would be required in the frequency division multiplexing telemetry subsystem or in the VCO mixer either of which would produce a major impact on the entire ECM instrumentation and telemetry systems design.

4.2 Incompatibility of Telemetry Subsystem Design with Real-Time Data Requirements

It was assumed by MMC that the only data from the subsystems or experiments of the ECM which would be required in real-time or near real-time for mission control would be that data contained in the 5.12 kbps PCM wavetrain generated by the PCM telemetry subsystem. In the proposed design, this wavetrain will always be transmitted in real-time, but will also always be frequency modulated on a subcarrier (IRIG FM proportional-bandwidth subcarrier channel 19) before modulating one of the VHF FM transmitters of the ECM. Consequently, the various stations of the MSFN must be equipped with a discriminator capable of demodulating IRIG subcarrier Channel 19 in order to retrieve the real-time 5.12 kbps PCM wavetrain and route it to a PCM decommutator prior to processing by the Remote Site Data Processor (RSDP). It should be noted that none of the stations of the MSFN are currently equipped with an IRIG FM proportional-bandwidth subcarrier channel 19 discriminator. However, each station of the MSFN is equipped with at least one set of discriminators for IRIG FM proportional-bandwidth subcarrier channels 1 through 18 and channels A through E. Consequently, the stations of the MSFN must be augmented with an IRIG subcarrier channel 19 discriminator to permit real-time processing of flight control data from the ECM.

The real-time output from the frequency division multiplexing telemetry subsystem which contains digital outputs from Group 2 experiments will also frequency modulate an IRIG subcarrier channel 19 before modulating a different VHF FM transmitter of the ECM. If real-time processing of these digital data were to become a requirement, it could not be done without the addition of an IRIG subcarrier channel 19 discriminator to the stations of the MSFN. It would probably be impractical in any event because of the third level of demodulation required (the output of the subcarrier channel 19 discriminator must be fed to discriminators for IRIG FM proportional-bandwidth subcarrier channels 5 through 9), because of the limited number of digital inputs available to the RSDP since each bit stream requires a separate input, and because of the many additional RSDP computer programs which would be required. In addition, these digital word lengths which will be greater than 8 bits (10, 12, and 20 bits) are incompatible with existing data processing systems of the MSFN and the Mission Control Center at Houston.

It should also be noted that the 3750 bps digital output signal from experiment S049 cannot be transmitted in real-time from the ECM to the MSFN under the proposed telemetry subsystem design nor can the output data from experiment S103. These data will always be recorded on-board the ECM in real-time and dumped to the MSFN in delayed-time.

4.3 Ground Control of ECM Subsystems and Experiments Severely Limited

In the proposed baseline design of the communications system of the ECM, ground command and control of ECM subsystems and ECM mounted experiments is limited to four discrete commands. This limitation may be unduly restrictive to mission planning for ECM subsystem and ECM mounted experiment operations during crew sleep periods and peak work load periods.

4.4 Tape Recorder-Reproducer Subsystem

The tape recorder-reproducer subsystem contained in the MMC proposed baseline ECM communications system is a modified version of the tape recorder reproducer subsystem of the Block II CSM of the Apollo Program. The proposed modifications include: (a) recording PCM data at a rate of 5.12 kbps at a tape speed of 3.75 ips instead of 1.6 kbps, and (b) playback tape speed reduced to 60 ips from 120 ips. The Leach Corporation, manufacturer of the Block II CSM tape recorder-reproducer subsystem, believes that the playback tape-speed reduction modification can be achieved without major difficulty.

It should be noted, however, that the record electronics of this tape recorder for PCM recording have been designed for a NRZ-L PCM bit stream plus a clock signal. The 5.12 kbps PCM signal output from the PCM telemetry subsystem of the ECM will be a RZ PCM bit stream. Some change in the proposed baseline design is indicated in this area.

The proposed mode of operation of this tape recorder-reproducer subsystem is to record at a tape speed of 3.75 ips until experiment S103 is activated when the record tape speed will be automatically switched to 15 ips and to dump at a tape speed of 60 ips. This proposed mode of operation may create an operational problem at the stations of the MSFN because of the change in both format and bit rate of the PCM signal received over a single link during dump of the on-board tape recorder-reproducer.

The effects of recording of the 3750 bps digital signal from experiment S049 on an analog channel should be investigated from a data degradation viewpoint. Characteristics of the 3750 bps digital signal such as the minimum number of bit transitions per unit time which would be required to conduct such an investigation were not available to MMC at this time.

The major drawback to the proposed use of the Block II CSM tape recorder-reproducer subsystem for ECM applications is that the subsystem would have to be requalified. This subsystem will be qualified in Apollo for 14 hours total operation time in a 14 day period. For this application in AAP, the tape recorder-reproducer subsystem would be required to operate essentially continuously for a full 14 days.

4.5 Time Correlation of Data

Some of the experiments to be conducted from the ECM require time correlation of the experiment data with both crew voice data and space vehicle attitude data to permit reduction and proper evaluation of the output data from the various experiments. In order to correlate these data in near-real time (post-pass data processing), all required data should be included on the same on-board tape recorder and be dumped to the MSFN simultaneously but not necessarily on the same radio frequency transmission link.

The recorder dump and/or real-time composite signal output from experiment S039 which is transmitted directly to the MSFN via an S-band transmission link includes timing reference information but does not include either crew voice notation information or space vehicle attitude information both of which are needed as a function of time for evaluation of this experiment output data.

Time correlation information will be included in both PCM outputs of the PCM telemetry subsystem and in the composite output of the frequency division multiplexing telemetry subsystem which will be recorded by tape recorder-reproducer subsystem of the ECM. Time correlation information will not be included in the 3750 bps digital signal but this signal will be recorded on the same tape recorder-reproducer as the outputs from the PCM telemetry and frequency division multiplexing subsystems of the ECM.

Space vehicle attitude information from the ECM Attitude Control and Pointing Subsystems will be included in both PCM outputs of the PCM telemetry subsystem but in no other place.

No voice information will be recorded by the ECM tape recorder-reproducer subsystem although the capability is available in the current tape recorder-reproducer subsystem design. However, including voice communications on the ECM tape recorder-reproducer would entail a major change in the ECM radio frequency transmission subsystem baseline design because an additional radio frequency transmitter would be required to permit dumping of all information stored on the tape recorder-reproducer to the MSFN simultaneously. The proposed communications system baseline design provides recording of voice information in the CM only.

4.6 Antenna Subsystem Radiation Patterns

During the conduct of some of the experiments, the CSM/ECM will be nominally stabilized with the roll axis of the CSM/ECM coincident with the local vertical and with the dome of the ECM pointed toward the Earth. In this orientation, it is likely that the ECM will physically mask the line-of-sight of the various S-band antenna elements of the CSM to portions of the Earth. The omni-directional S-band antenna subsystem of the CSM will consists of four elements located on the conical surface of the CM and spaced approximately 90 degrees apart. Radiation from only one of these four elements will be possible at any given time. Testing of at least a scale module of the CSM/ECM space vehicle would be required to ascertain the actual CSM antenna radiation pattern perturbations caused by the presence of the ECM and to determine the operational requirements imposed on the crew for manual selection of S-band omni-directional antenna elements as a function of attitude during a pass over a station of the MSFN.

The VHF omni-directional antenna subsystem and the S-band omni-directional antenna subsystem of the ECM as described in the baseline design will each consist of four antenna elements located on the periphery of the dome and spaced approximately 90 degrees apart. The four elements of each antenna subsystem will radiate simultaneously. It is expected that severe scalloping of the resultant radiation patterns of the ECM VHF and S-band antenna subsystems will occur because of the constructive and destructive interferences between the radiation patterns of the individual antenna elements of either antenna subsystem, especially for the S-band antenna subsystem. This may not be a problem if the attitude of the CSM/ECM was stabilized as it will be during the conduct of the experiments. However, it is unlikely that the space vehicle attitude will be stabilized throughout the mission duration because of the limited stabilization fuel budget. Therefore it is likely that a nearly true omni-directional antenna radiation pattern will be required to enable successful communication between the ECM and the MSFN during all periods of line-of-sight between the CSM/ECM and a suitably equipped station of the MSFN.

4.7 Equipment Reliability and Contingency Modes of Operation

As stated earlier, the proposed ECM communications system baseline design calls for the use of a modified version of the tape recorder-reproducer subsystem carried by the Block II CSM of the Apollo Program which includes a single tape recorder-reproducer without a backup unit. The baseline design also precludes the transmission of output data from experiments S049 and S103 to the MSFN in real-time. Data from these experiments must first be recorded by the ECM tape recorder-reproducer subsystem and then later be dumped and transmitted to the MSFN. Consequently, failure of the tape recorder-reproducer on the ECM would prevent retrieval of any data from experiments S049 and S103 as well as any other data in delayed-time. Although limited amounts of data from other experiments conducted on the ECM as well as ECM subsystem status and performance data could be gathered during those periods of the ECM mission when the CSM/ECM was within line-of-sight a suitably equipped station of the MSFN, loss of the ECM tape recorder-reproducer would make continuing conduct of experiments impractical or impossible. Thus, with mission success depending on the continuing operation and availability of the ECM tape recorder-reproducer subsystem and noting that qualification tests of the Apollo Program version of this subsystem show expected trouble-free operation times to be of the order of one day or less, equipment redundancy appears to be indicated for addition to the design of this subsystem for application to the ECM.

Except for the real-time 5.12 kbps signal output of the PCM telemetry subsystem and the real-time composite signal output of the frequency division multiplexing telemetry subsystem, the failure of any transmitter on the ECM would prevent some experiemnt data from ever being retrieved on the Earth. The two real-time telemetry signals mentioned above may be transmitted to the MSFN via switch selection by either one of two transmitters providing some limited operational flexibility for contingencies. However, if one of the four radio frequency transmitters were lost, data from either (a) experiment S039, (b) experiment S103 and delayed-time PCM data, (c) experiment S049, or (d) delayed-time output of the frequency division multiplexing telemetry subsystem would be unretrievable depending upon which of the transmitters had failed. The capability for time-sharing of the operating transmitters with all signals appears to minimize the impact of the failure of any transmitter on mission success.

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Attachments
Table 1
Figure 1

TABLE 1

Mission AAP-1A Approved Experiments List

	Experiment	Group
S039	Day/Night Camera	2
S043	IR Temperature Sounding	2
S049	IR Interferometer Spectrometer	2
S050	IR Temperature Profile Radiometer	2
S075	Electronically Scanned Microwave Radiometer	2
S100	Metric Camera/Stellar	1
S101	Multispectral Photography	1
S102	IR Dual Channel Scanner	1
S103	Short Wavelength Spectrometer	1
S104	Microwave Temperature Sounder	2
S105	Radar Altimeter Scatterometer	2

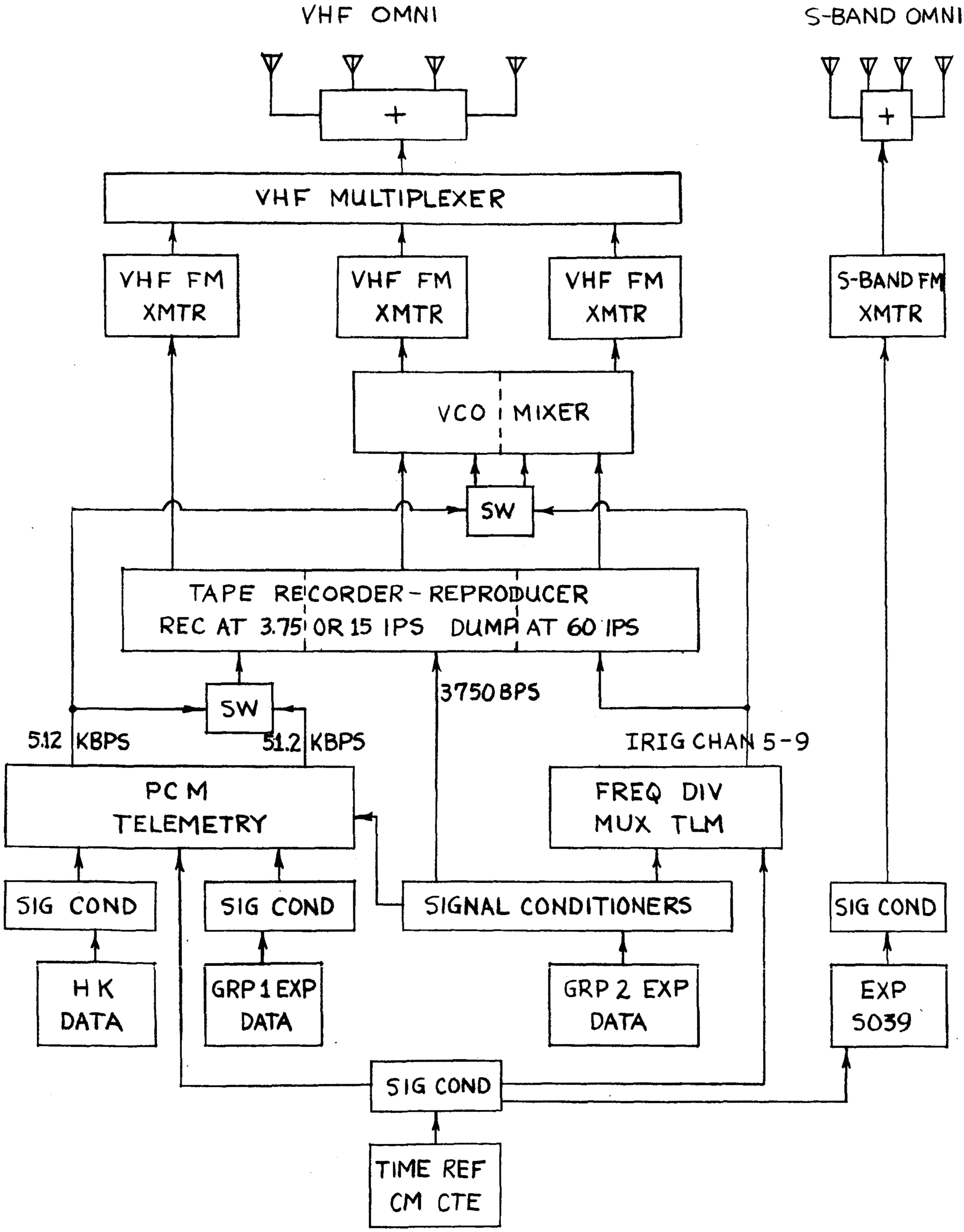

FIGURE 1 - TELEMETRY SYSTEM OF ECM

BELLCOMM, INC.

Subject: Review of Proposed Communication System for the Experiment Carrier Module for AAP Mission 1A

From: A. G. Weygand

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